Residential Load Management Technologies

MEASURE OVERVIEW

Description: This measure includes the following residential load management technologies: A/C cycling, electric heat cycling, electric water heater curtailment, and electric thermal storage for space heating. Load management programs are primarily intended to reduce peak electrical demand and/or shift energy use to off-peak hours. Therefore, the primary impact is peak kW savings, though secondary kWh savings also result except from electric thermal storage.

Actions: Modify, Replace Working, Replace on Fail, New Construction

Algorithms: Unit kWh Savings per Year = (average # of events) x (kWh savings per event)
Unit Peak kW Savings = kW savings per event
Measure Lifetime (years) = 15 (Ref. 2)
Unit Participant Incremental Cost = See Table 4

Where:

Average # of events = average number of load control events during a typical year, provided by utility
kWh savings per event = modeled net kWh savings per load control event per installation, including snapback (See Tables 1-3)
kW savings per event = modeled peak kW savings per load control event per installation (See to Tables 1-3)

Required Inputs from Utility: Load control technology installed (A/C cycling, electric heat cycling, electric water heater curtailment, electric thermal storage for space heating), installation location (county), average number of load control events in a typical year.

Optional Inputs from Utility: Cost of load control equipment, installation, and any metering costs.

DEEMED INPUT TABLES

Table 1: Modeled kWh and kW savings per Load Control Event per Unit, Zone 1 (Ref. 1)

Technology	kWh Savings	Summer kW Savings	Winter kW Savings
A/C Cycling	28.81	0.687	0.000
Electric Heat Cycling	2.54	0.000	2.000
DHW Curtailment	0.58	0.540	0.760
Electric Thermal Storage	0.00	0.000	26.900

Table 4: Default Incremental Cost (Equipment plus Installation) by Technology

Technology	Incremental Cost	Ref.
A/C Cycling	$200	2
Electric Heat Cycling	$200	2
DHW Curtailment Summer	$200	2
DHW Curtailment Winter	$200	2
Electric Thermal Storage	$11,700	3, 4

METHODOLOGY AND ASSUMPTIONS

Current Smart Measure™ implementation of this measure on ESP® does not support winter kW savings at this time.

Default incremental costs include equipment and installation only. If the program includes meter installation, some portion of these costs should be included in a cost-effectiveness analysis.

Energy and demand impacts are based on simulation results by Michaels Energy using BEopt and EnergyPlus for a median residential home as defined in Ref. 1 in Zones 1, 2, and 3.

- A demand response event was simulated on July 15 and the air conditioning was cycled every 15 minutes during the event, which lasted for 7 hours, from 1 pm to 8 pm. A domestic water heater demand response event was also simulated on these homes on both winter (January 28) and summer peak days. The winter demand event occurred from 4 pm to 7 pm. TMY3 (typical meteorological year, third collection) weather data was used in all of the simulations using the designated cities for each climate zone (Minneapolis, Saint Cloud, Duluth). The summer event schedule was selected based on the data provided by the two utilities in this study, which showed that 1 pm to 8 pm was the most common control period. The winter event schedule was selected based on the fact that the IOU triggers events on winter afternoons and the G&T Co-op's website shows that their winter loads peak in the late afternoon and early evening hours. Although there are a variety of control methods, 50% cycling of air conditioners was used in this model because it is the most commonly used scheme in Minnesota. Load curtailment during the event was used for domestic water heaters, since that is the most common form of control for those systems, according to the websites of both of the utilities. July 15 was selected as the summer peak day because the TMY3 weather data showed that the outdoor air temperature was near the annual peak and the following day had a nearly identical temperature profile in order to properly evaluate snapback effects that may linger into the next day after a demand response event (Ref. 1).

- January 28th was selected for the winter event (except in Minneapolis; see footnote) because it was a typical winter day in the TMY3 weather data and the following day's temperature profile was very similar.

- TMY3 data were used for all simulations. Duluth was selected for Zone 1; St. Cloud was selected for Zone 2; and Minneapolis was selected for Zone 3.

- A/C Cycling
  - o A load control event was simulated on July 15 between 1 pm and 8pm. The A/C was cycled every 15 minutes during the event.

- Domestic hot water (DHW) curtailment
  - o Load control events were simulated on both winter (January 28 except for Zone 3) and summer (July 15) peak days. The winter demand event occurred from 4 pm to 7 pm. The summer demand event occurred from 1 pm to 8 pm.
  - o The weather file data for Minneapolis on January 28 contained temperatures well below the design temperature for Minneapolis, while the other two climates had temperatures above their design temperatures on that data. Therefore, January 7 was selected for Minneapolis as a suitable replacement since it had a similar daily load profile at more typical temperatures with the following day (January 8) having a similar load profile.

- Electric heat cycling
  - o Winter demand events occurred from 1 pm to 8 pm on January 28 except for Zone 3.

- Electric thermal storage
  - o Days were selected to match the heating design temperatures in the TRM: Zone 1: -22F, Zone 2: -16.5F, Zone 3: -14.5F. In each case, the following day had a similar load profile.

REFERENCES

1. Michaels Energy. Demand Response and Snapback Impact Study. August 2013. Prepared for Minnesota Department of Commerce, Division of Energy Resources under a grant through the Conservation Applied Research and Development (CARD) program. http://mn.gov/commerce/energy/topics/conservation/Applied-Research-Development/About-CARD.jsp, accessed February 11, 2014.
2. Average of pricing data from two Minnesota utilities. Includes equipment and installation costs. Does not include metering costs.
3. Efficiency Maine. Energy Efficient Heating Options: Pilot Projects and Relevant Studies. April 8, 2013. http://www.efficiencymaine.com/docs/EMT_Energy-Efficient-Heating-Options-Report_2013_4_8.pdf, accessed February 11, 2014. Average cost of electric thermal storage furnace = $13,000.

4. Web research on 2.11.14 and 2.12.14. Average price of 25 kW electric forced-air furnace = $1,300. Models: WMA60-25 (sold under names of Hamilton Home Products and Winchester 81,912 BTU 5 TON Multi-Position Electric Furnace); 21D25 (Nortron D-series 25 kW). Retailers: Northern Tool, Ecco Supply, Home Depot, Lowes.

Residential HVAC - Central AC/ASHP

MEASURE OVERVIEW

Description: This measure includes replacement of failed or working central AC system or ASHP in existing homes with high efficiency units, as well as installation of high efficiency AC systems in new homes. Savings for replacement of working units are in reference to existing unit.

Actions: Replace on Fail, Replace Working, New Construction

Algorithms: Unit kWh Savings per Year for AC system = Size x $EFLH_{Cool}$ x (12 / SEER_Base - 12 / SEER_Eff)
Unit kWh Savings per Year for ASHP = Size x $EFLH_{Cool}$ x (12 / SEER_Base - 12 / SEER_Eff) + (Size x $EFLH_{Heat}$) x (12 / $HSPF_{base}$ - 12 / $HSPF_{eff}$)
Unit Peak kW Savings = CF x Size x (12/EER_Base - 12/EER_Eff)
Measure Lifetime (years) = 18 (Ref. 1)
Unit Participant Incremental Cost = See Table 3, 4. Incremental equipment cost only, labor is not included

Where:

Size = Unit capacity in tons (1 ton = 12,000 btu/h)
$EFLH_{Cool}$ = Equivalent Full Load Cooling Hours. See Table 1.
SEER_Base = SEER of baseline or existing unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided (Ref. 4), (SEER_Base = 13 if unknown)
EER_Base = EER of baseline or existing unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (Ref. 4), (EER_Base = 13 X 0.875 = 11.4 if unknown)
SEER_Eff = SEER of new high efficiency unit provided by customer/contractor, or use SEER = EER / 0.875 if EER is provided (Ref. 4)
EER_Eff = EER of new high efficiency unit provided by customer/contractor, or use EER = SEER x 0.875 if SEER is provided (Ref. 4)
CF = Coincidence Factor, assumed to be 0.9 (Ref. 5)
$HSPF_{base}$ = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use HSPF_base = 7.7 if unknown (Ref. 6)
$HSPF_{eff}$ = Heating system performance factor of efficient ASHP, provided by customer/contractor
$EFLH_{Heat}$ = Equivalent Full Load Hours Heating. See Table 2

Required from Customer/Contractor: Equipment size (tons), SEER or EER of new equipment, SEER or EER of existing equipment (if program includes early replacements), HSPF of new equipment (ASHP only), HSPF of existing equipment (ASHP only, if program includes early replacements), existing equipment condition (working or failed, if program includes early replacements), building type (single family / multifamily*), project location (county).

* Multifamily includes duplexes, townhomes, and multifamily buildings with 3 or more units

DEEMED INPUT TABLES

Table 1. Effective Full Load Cooling Hours ($EFLH_{Cool}$) by Climate Zone (Ref. 3)

Location	Equivalent Full Load Cooling Hours	
	Single Family	**Multifamily***
Zone 1 (Northern MN)	282	302
Zone 2 (Central MN)	393	490
Zone 3 (Twin Cities/Southern MN)	452	536

*Includes duplex, townhome, and multifamily buildings with 3 or more units

Table 2. Equivalent Full Load Heating Hours ($EFLH_{Heat}$) by Climate Zone (Ref. 7)

Location	Equivalent Full Load Heating Hours	
	Single Family	**Multifamily***
Zone 1 (Northern MN)	2,569	
Zone 2 (Central MN)	2,494	
Zone 3 (Twin Cities/Southern MN)	2,257	

*Includes duplex, townhome, and multifamily buildings with 3 or more units

Table 3: AC Incremental cost (Ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 14.5	$178
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908
Average	$530

Table 4. ASHP Incremental cost (Ref. 2)

Efficiency Level	Cost per Ton
SEER 14	$137
SEER 15	$274
SEER 16	$411
SEER 17	$548
SEER 18	$685

METHODOLOGY AND ASSUMPTIONS

$EFLH_{Cool}$ data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{Heat}$ were determined from Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

NOTES

The prior national standards for central air conditioners and heat pumps, which raised the minimum Seasonal Energy Efficiency Ratio (SEER) requirement from 10 to 13, became effective in 2006. In January 2010, HVAC manufacturer representatives and efficiency advocates presented a negotiated consensus agreement to DOE to increase efficiency standards for central air conditioners and heat pumps. The consensus agreement included regional standards for three regions: the South, the Southwest, and the North, reflecting varying HVAC needs for each climate. DOE issued a direct final rule (DFR) in June 2011 based on the standard levels in the consensus agreement. These DFR became effective on October 25, 2011. The new standards increase the minimum cooling efficiency requirement to SEER 14 for split system central air conditioners in the South and the SW while maintaining the SEER 13 standard for the North. The new standards also include EER (Energy Efficiency Ratio) requirements for the SW region to ensure efficient operation at high outdoor temperatures. For heat pumps, the standards raise the cooling efficiency requirement to SEER 14 for all three regions and also increase the heating efficiency requirements. The standards will became effective on January 1, 2015. The requirement pertains to the manufacture of units with an 18 month grace period allowed for the sale AC units and a similar period expected for ASHP units.

REFERENCES

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc. June 2007. <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>
2. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
3. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.
4. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment.
5. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
6. Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.ht ml.
7. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.

Residential HVAC - Ground Source Heat Pump Systems

MEASURE OVERVIEW

Description: This measure includes replacement of non-working and working ground source heat pump (GSHP) equipment and replacement of non-working and working furnace and air conditioner equipment with ground source heat pump systems (GSHP)

Actions: Replace on Fail, Replace Working, New Construction

Algorithms: *Baseline Heating, Existing <u>Electric Resistance</u> :*

Unit Heating kWh Baseline (GSHP) per Year = Size x (3.52 / (Rated_COP_Base) x COP_Adjust)) x $EFLH_{Heat}$

Baseline Cooling, Existing A/C:

Unit Cooling kWh Baseline (GSHP) per Year = Size x (12 / Rated_EER_Base) x EER_Adjust) x $EFLH_{cool}$

Baseline Heating, Gas Furnace:

Unit Heating Dth Baseline (Furnace) per Year = Btuh_input / 1,000,000 x (1 / AFUE_Base) x $EFLH_{Heat}$

Baseline Cooling, Split System A/C:

Unit Cooling kWh Baseline (Split A/C) per Year = Size x (12 / SEER_Base) x $EFLH_{cool}$

Proposed Heating, GSHP:

Unit Heating Proposed kWh per Year = Size x (3.52 / Rated_COP_Proposed) x COP_Adjust x $EFLH_{Heat}$

Proposed Cooling, GSHP:

Unit Cooling Proposed kWh per Year = Size x (12 / Rated_EER_Proposed) x EER_Adjust x $EFLH_{cool}$

Savings, Existing <u>Electric Resistance and Split System A/C:</u>

Unit kWh Savings per Year = (Unit Heating kWh Baseline (GSHP) per Year + Unit Cooling kWh Baseline (GSHP) per Year) - (Unit Heating Proposed kWh per Year + Unit Cooling Proposed kWh per Year)

Unit Peak kW Savings = (Unit Cooling kWh Baseline (GSHP) per Year - Unit Cooling Proposed kWh per Year) / $EFLH_{cool}$ x CF

Measure Lifetime (years) = 18 (Ref. 1)

Unit Participant Incremental Cost = $150/ton incremental cost when replacing existing ground source heat pump (Ref. 2), $900/ton cost when installing new ground source heat pump, i.e., replacing a furnace / split system air conditioner (Ref. 3, 4)

Where:

Size = Heat pump or split system A/C capacity in tons (1 ton = 12,000 btu/h)
Btuh_input = furnace capacity in Btu/hr
3.52 = unit conversion, tons to kW
1,000,000 = unit conversion, BTU per Dtherm
Rated_COP_Base = 3.1, rated COP in heating mode for the baseline ground source heat pump (Ref. 5)
Rated_COP_Proposed = actual rated COP in heating mode for the proposed ground source heat pump
Rated_EER_Base = 13.4, rated EER in cooling mode for the baseline ground source heat pump (Ref. 5)
Rated_EER_Proposed = actual rated EER in cooling mode for the proposed ground source heat pump
SEER_Base = 13.0, baseline split system A/C SEER (Ref. 6)
AFUE_Base = AFUE rating of baseline furnace: 80% if replace existing furnace, 90% if new construction (Ref. 7)
COP_Adjust = 81.6%, adjustment factor from rated COP to average COP (Ref. 3)
EER_Adjust = 89.1%, adjustment factor from rated EER to average EER (Ref. 3)
$EFLH_{Heat}$ = Equivalent Full Load Heating Hours, see Table 1
$EFLH_{Cool}$ = Equivalent Full Load Cooling Hours, see Table 2
CF = Coincidence Factor, assumed to be 0.9 (Ref. 2)

Required from Customer/Contractor:
1. Existing HVAC system type (furnace with split system A/C, ground source heat pump, electric heat with split system A/C)
2. Existing system size
3. Proposed system size
4. Proposed system heating COP
5. Proposed system cooling EER

DEEMED INPUT TABLES

Table 1. Effective full load heating hours ($EFLH_{Heat}$) by Climate Zone (Ref. 8)

Location	Equivalent Full Load Heating Hours	
	Single Family	**Multifamily***
Zone 1 (Northern MN)	2,569	2,569
Zone 2 (Central MN)	2,494	2,494
Zone 3 (Twin Cities/Southern MN)	2,257	2,257

*Includes duplex, townhome, and multifamily buildings with 3 or more units

Table 2. Effective full load cooling hours ($EFLH_{Cool}$) by Climate Zone (Ref. 9)

Location	Equivalent Full Load Cooling Hours	
	Single Family	**Multifamily***
Zone 1 (Northern MN)	282	228
Zone 2 (Central MN)	393	473
Zone 3 (Twin Cities/Southern MN)	452	616

*Includes duplex, townhome, and multifamily buildings with 3 or more units

NOTES

For baseline heating system = electric resistance, use 'Baseline Heating, Existing GSHP' formula with COP = 1.0 and omit the COP_Adjust input.

Proposed heat pump should meet Energy Star minimum requirements

For multi-stage ground source heat pumps, average the highest and lowest EER and COP, per Energy Star guidelines (www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps)

$EFLH_{Cool}$ data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{Heat}$ were determined from Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

REFERENCES

1. Measure Life Report - Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf
2. Comparison of Electric/Gas Fired Unitary equipment costs from DEER 2008 Database Technology and Measured Cost Data and Electric/Gas Fired Unitary and Heat Pump equipment costs from RSMeans Mechanical Cost Data.
3. Performance, Emissions, Economic Analysis of Minnesota Geothermal Heat Pumps, Michaels Energy for Minnesota Department of Commerce, April 2008. http://www.michaelsenergy.com/PDFs/Minnesota%20GHP.pdf
4. Personal communication with Eric O'Neil of Michaels Energy, 7/30/15. Eric provided HVAC capacity for the building types modeled in Ref. 3.
5. ASHRAE Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1B, Ground Source Heat Pump 32°F entering water for heating, 77°F entering water for cooling.
6. Title 10, Code of Federal Regulations, Part 430 - Energy Conservation Program for Consumer Products, Subpart C, Section 430.32. January 1, 2013. http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
7. US Department of Energy. Though the federal minimum efficiency is 78% there are very few models available at this efficient; a review of AHRI shows that most low efficiency units are 80%. http://buildingsdatabook.eere.energy.gov/ChapterIntro7.aspx
8. FES scaled annual heating loads from those provided in the Illinois Technical Reference Manual based on Minnesota weather data.
9. Calculated through energy modeling of California DEER study prototypes modified by Illinois field data with TMY3 Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) by FES 2012.
10. 0.9 is a typical value used for central HVAC equipment in many programs. The range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.

Residential Lighting - Lighting End Use

MEASURE OVERVIEW

Description: The residential lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, In Services Rates, and coincident factors. The following section provides the algorithms used for energy savings and the tables of supporting information.

Algorithms: Unit kWh Savings per Year = (kW_{base} - kW_{EE}) x Hrs x HVAC_Cooling_kWh_Savings_Factor
Unit Peak kW Savings = CF x (kW_{base} - kW_{EE}) x HVAC_Cooling_kW_Savings_Factor
Measure Lifetime (years) = See each technology section.
Unit Participant Incremental Cost = See each technology section.

Where:

kW_{base} = Deemed average wattage of baseline luminaire per each section
kW_{EE} = Deemed average wattage efficient luminaire per each section
Hrs = Deemed annual operating hours from Table 2 based on space type
CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.
HVAC_Cooling_kWh_Savings_Factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.
HVAC_Cooling_kW_Savings_Factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.
HVAC_Heating_Penalty_Factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quatities (retrofits only), Installed fixtures and quantities, space type (interior living quarters, multifamily* common areas, or exterior/unconditioned space), HVAC System (heating only, heating & cooling, exterior/unconditioned)

* Multifamily includes 3+ unit residential buildings

DEEMED INPUT TABLES

Table 1: HVAC Interactive Factors by HVAC System (Ref. 1)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Space Type	**Heating Only**	**Heating & Cooling**	**Heating Only**	**Heating & Cooling**	**Heating Only or Heating & Cooling**
Interior Living Quarters	1.000	1.248	1.000	1.075	-0.0029
Multifamily Common Areas	1.000	1.248	1.000	1.075	-0.0029
Exterior/Unconditioned Space	1.000	1.000	1.000	1.000	0.0000
Interior Living Quarters - Cooling Unknown	1.000	1.160	1.000	1.048	-0.0029
Multifamily Common Areas - Cooling unknown	1.000	1.110	1.000	1.048	-0.0029

*For non direct install delivery methods use the Cooling Unknown HVAC values.

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 2 and 5) and Annual Operating Hours by Space Type (see table for references)

Space Type	CF	Hrs	Reference
Interior Living Quarters	9.5%	938	3
Multifamily Common Areas	75.0%	5,950	4
Exterior/Unconditioned Space	0.0%	1,825	3

METHODOLOGY AND ASSUMPTIONS

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation.

The prototypes building models are based on the California DEER study prototypes, and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

REFERENCES

1. Calculated through energy modeling be FES 2012.
2. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. "ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols" http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf
   "Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team" http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf
3. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 7.5 based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.
4. Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
5. Coincidence factor is based on healthcare/clinic value (used as proxy for multifamily common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types.
6. Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; http://www.ilsag.info/evaluation-documents.html.
7. In service rate for Retail CFLs is based upon recommendation in the Uniform Methods Project to use data from the Navigant Consulting and Apex Analytics (2013) study.
8. In Service rates provided for the CFL and LED lamps in a kit only. Kits provided free to students through the school, with education program. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10; http://www.ilsag.info/evaluation-documents.html
9. Opt-in program to receive kits via mail, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10, as above.

Savings Table

kW_EE	kW_Base	kWh Savings	kW Savings
4	29	25.21	0.031
5	29	24.20	0.030
6	29	23.19	0.029
7	29	22.18	0.027
8	43	35.29	0.044
9	43	34.28	0.042
9.5	43	33.78	0.042
10	43	33.28	0.041
11	43	32.27	0.040
12	43	31.26	0.039
13	53	40.33	0.050
14	53	39.33	0.049
15	53	38.32	0.047
16	72	56.47	0.070
17	72	55.46	0.069
18	72	54.45	0.067
19	72	53.44	0.066
20	72	52.43	0.065
21	72	51.43	0.064
22	72	50.42	0.062
23	72	49.41	0.061
25	125	100.84	0.125
26	125	99.83	0.124
28	125	97.81	0.121
30	125	95.79	0.119
32	150	118.99	0.147
40	200	161.34	0.200
42	200	159.32	0.197
55	300	247.05	0.306
68	300	233.94	0.290

C/I HVAC - Heat Pump Systems

MEASURE OVERVIEW

Description: This measure includes replacement of non-working and working unitary air source heat pump (ASHP), ground water source heat pump (GWSHP) and ground source heat pump (GSHP) equipment. This measure analyzes the heating and cooling savings potential of the installation of higher efficinecy unitary heat pump equipment.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace Working, Replace on Fail, New Construction

Algorithms: Unit kWh Savings per Year = (Size x $EFLH_{Cool}$) x (12 / $SEER_{Base}$ - 12 / $SEER_{EE}$) + (Size x $EFLH_{Heat}$) x (12 / $HSPF_{Base}$ - 12 / $HSPF_{EE}$) (ASHP units less than 5 tons)

Unit kWh Savings per Year = (Size x $EFLH_{Cool}$) x (12 / $IEER_{Base}$ - 12 / $IEER_{EE}$) + (Size x $EFLH_{Heat}$) x (3.52 / COP_{Base} - 3.52 / COP_{EE})

Unit Peak kW Savings = Size x (12 / EER_{Base} - 12 / EER_{EE}) x CF

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = See Table 3 (Ref. 2) or Table 4 (Ref. 3)

Where:

CF = Deemed coincidence factor, equal to 0.9 (Ref. 4)

COP_{Base} = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor. If unknown see Table 3 (Ref. 5)

COP_{EE} = Heating system performance factor of eefficient ASHP, provided by customer/contractor

EER_{Base} = Energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy coded minimal efficiency ratings. See Table 3 (Ref. 5)

EER_{EE} = Energy efficiency ratio of the high efficiency equipment, provided by the customer. If unknown, use EER = 0.875 x SEER (Ref. 7)

$EFLH_{Cool}$ = Equivalent full load cooling hours based on the building type. See Table 1 (Ref. 7)

$EFLH_{Heat}$ = Equivalent full load heating hours based on the building type. See Table 2 (Ref. 8)

$HSPF_{Base}$ = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use $HSPF_{Base}$ = 7.7 if unkown (Ref. 5)

$HSPF_{EE}$ = Heating system performance factor of efficient ASHP, provided by customer/contractor

Size = Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

$IEER_{Base}$ = Integrated energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3 (Ref. 5)

$IEER_{EE}$ = Integrated energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor

$SEER_{Base}$ = Seasonal energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3 (Ref. 5)

$SEER_{EE}$ = Seasonal energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor

Required from Customer/Contractor: Equipment size (tons), IEER or EER of new equipment, IEER or EER of existing equipment (if program includes early replacements), HSPF or COP of new equipment, HSPF or COP of existing equipment (if program includes early replacements), exisitng equipment condition (working or failed, if program includes early replacements), building type (see Table 1), project location (county)

DEEMED INPUT TABLES

Table 1: Equivalent Full Load Hours of cooling ($EFLH_{Cool}$) per zone in Minnesota by building type (Ref.7)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	644	781	857
Education - Community College/University	290	352	386
Education - Primary	461	559	613
Education - Secondary	461	559	613
Health/Medical - Clinic	787	955	1,048
Health/Medical - Hospital	1,837	2,228	2,444
Lodging	867	1,051	1,153
Manufacturing	637	772	847
Office - Low Rise	609	739	811
Office - Mid Rise	566	687	753
Office - High Rise	820	995	1,092
Restaurant	684	830	910
Retail - Large Department Store	536	651	714
Retail - Strip Mall	555	673	738
Warehouse	204	247	271
Other/Miscellaneous	737	894	980

Table 2: Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref.8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	2,048	1,974	1,772
Education - Community College/University	2,141	2,063	1,853
Education - Primary	2,599	2,505	2,249
Education - Secondary	2,599	2,505	2,249
Health/Medical - Clinic	2,425	2,337	2,099
Health/Medical - Hospital	2,748	2,648	2,378
Lodging	2,515	2,424	2,177
Manufacturing	1,516	1,462	1,312
Office - Low Rise	2,133	2,056	1,846
Office - Mid Rise	2,376	2,290	2,056
Office - High Rise	2,864	2,761	2,479
Restaurant	2,027	1,954	1,754
Retail - Large Department Store	1,913	1,844	1,656
Retail - Strip Mall	1,846	1,779	1,598
Warehouse	2,031	1,958	1,758
Other/Miscellaneous	2,304	2,220	1,994

Table 3: Deemed baseline efficiency for heating and cooling, incremental costs

Equipment	$SEER_{Base}$ (Ref. 5)	$IEER_{Base}$ (Ref. 5)	EER_{Base} (Ref. 5)	$HSPF_{Base}$ (Ref. 5)	COP_{Base} (Ref. 5)	Incremental Cost (Ref. 2)
ASHP Units less than or equal to 5.4 tons	13.0	-	11.4	7.7	-	See Table 4
ASHP Units 5.5 - 11.3 tons	-	11.2	11.0	-	3.3*	$165/ton
ASHP Units 11.4 - 19.9 tons	-	10.7	10.6	-	3.2*	$150/ton
ASHP Units 20 - 63.3 tons	-	9.6	9.5	-	3.2*	$140/ton
GSHP Units (closed loop)	-	15.3	13.4**	-	3.6	$150/ton
GWSHP Units (open loop)	-	18.5	16.2***	-	3.1	$150/ton

* COP based upont 47°F DB and 43°F WB outdoor air temperature
** COP based upon GWSHP 77°F entering water.
*** COP based upon GWSHP 59°F entering water.

Table 4: ASHP units 5.4 tons or less incremental cost (Ref. 3)

Efficiency Level	Incremental Cost
SEER 14	$137/ton
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

METHODOLOGY AND ASSUMPTIONS

$EFLH_{Cool}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{Heat}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

NOTES

Base line ground source heat pump SEER is based upon an entering temperature of 59°F entering water temperature.

REFERENCES

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, by GDS Associates, Inc. June 2007, pg. 6.
2. Comparison of Electric/Gas Fired Unitary equipment costs from DEER 2008 Database Technology and Measured Cost Data and Electric/Gas Fired Unitary and Heat Pump equipment costs from RSMeans Mechanical Cost Data.
3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
5. Minnesota 2015 Energy Code - TABLE C403.2.3(2) MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS.
6. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment.
7. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) 2012.
8. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.

C/I HVAC - Heat Pump Systems

MEASURE OVERVIEW

Description: This measure includes replacement of non-working and working unitary air source heat pump (ASHP), ground water source heat pump (GWSHP) and ground source heat pump (GSHP) equipment. This measure analyzes the heating and cooling savings potential of the installation of higher efficinecy unitary heat pump equipment.

The incremental cost is associated with base equipment cost and does not include any installation costs.

Actions: Replace Working, Replace on Fail, New Construction

Algorithms: Unit kWh Savings per Year = (Size x $EFLH_{Cool}$) x (12 / $SEER_{Base}$ - 12 / $SEER_{EE}$) + (Size x $EFLH_{Heat}$) x (12 / $HSPF_{Base}$ - 12 / $HSPF_{EE}$)
(ASHP units less than 5 tons)

Unit kWh Savings per Year = (Size x $EFLH_{Cool}$) x (12 / $IEER_{Base}$ - 12 / $IEER_{EE}$) + (Size x $EFLH_{Heat}$) x (3.52 / COP_{Base} - 3.52 / COP_{EE})

Unit Peak kW Savings = Size x (12 / EER_{Base} - 12 / EER_{EE}) x CF

Measure Lifetime (years) = 15 (Ref. 1)

Unit Participant Incremental Cost = See Table 3 (Ref. 2) or Table 4 (Ref. 3)

Where:

CF = Deemed coincidence factor, equal to 0.9 (Ref. 4)

COP_{Base} = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor. If unknown see Table 3 (Ref. 5)

COP_{EE} = Heating system performance factor of eefficient ASHP, provided by customer/contractor

EER_{Base} = Energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy coded minimal efficiency ratings. See Table 3 (Ref. 5)

EER_{EE} = Energy efficiency ratio of the high efficiency equipment, provided by the customer. If unknown, use EER = 0.875 x SEER (Ref. 7)

$EFLH_{Cool}$ = Equivalent full load cooling hours based on the building type. See Table 1 (Ref. 7)

$EFLH_{Heat}$ = Equivalent full load heating hours based on the building type. See Table 2 (Ref. 8)

$HSPF_{Base}$ = Heating system performance factor of baseline or existing ASHP, provided by customer/contractor or use $HSPF_{Base}$ = 7.7 if unkown (Ref. 5)

$HSPF_{EE}$ = Heating system performance factor of efficient ASHP, provided by customer/contractor

Size = Nominal Cooling capacity in tons of the new equipment (1 ton = 12,000 btu/h)

$IEER_{Base}$ = Integrated energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3 (Ref. 5)

$IEER_{EE}$ = Integrated energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor

$SEER_{Base}$ = Seasonal energy efficiency ratio of the baseline equipment, based on the 2015 Minnesota Energy Code requirements. See Table 3 (Ref. 5)

$SEER_{EE}$ = Seasonal energy efficiency ratio of the high efficiency equipment, provided by the customer/contractor

Required from Customer/Contractor: Equipment size (tons), IEER or EER of new equipment, IEER or EER of existing equipment (if program includes early replacements), HSPF or COP of new equipment, HSPF or COP of existing equipment (if program includes early replacements), exisitng equipment condition (working or failed, if program includes early replacements), building type (see Table 1), project location (county)

DEEMED INPUT TABLES

Table 1: Equivalent Full Load Hours of cooling ($EFLH_{Cool}$) per zone in Minnesota by building type (Ref.7)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	644	781	857
Education - Community College/University	290	352	386
Education - Primary	461	559	613
Education - Secondary	461	559	613
Health/Medical - Clinic	787	955	1,048
Health/Medical - Hospital	1,837	2,228	2,444
Lodging	867	1,051	1,153
Manufacturing	637	772	847
Office - Low Rise	609	739	811
Office - Mid Rise	566	687	753
Office - High Rise	820	995	1,092
Restaurant	684	830	910
Retail - Large Department Store	536	651	714
Retail - Strip Mall	555	673	738
Warehouse	204	247	271
Other/Miscellaneous	737	894	980

Table 2: Equivalent Full Load Hours of heating per zone in Minnesota by building type (Ref.8)

Building Type	Zone 1	Zone 2	Zone 3
Convenience Store	2,048	1,974	1,772
Education - Community College/University	2,141	2,063	1,853
Education - Primary	2,599	2,505	2,249
Education - Secondary	2,599	2,505	2,249
Health/Medical - Clinic	2,425	2,337	2,099
Health/Medical - Hospital	2,748	2,648	2,378
Lodging	2,515	2,424	2,177
Manufacturing	1,516	1,462	1,312
Office - Low Rise	2,133	2,056	1,846
Office - Mid Rise	2,376	2,290	2,056
Office - High Rise	2,864	2,761	2,479
Restaurant	2,027	1,954	1,754
Retail - Large Department Store	1,913	1,844	1,656
Retail - Strip Mall	1,846	1,779	1,598
Warehouse	2,031	1,958	1,758
Other/Miscellaneous	2,304	2,220	1,994

Table 3: Deemed baseline efficiency for heating and cooling, incremental costs

Equipment	$SEER_{Base}$ (Ref. 5)	$IEER_{Base}$ (Ref. 5)	EER_{Base} (Ref. 5)	$HSPF_{Base}$ (Ref. 5)	COP_{Base} (Ref. 5)	Incremental Cost (Ref. 2)
ASHP Units less than or equal to 5.4 tons	13.0	-	1.4	7.7	-	See Table 4
ASHP Units 5.5 - 11.3 tons	-	11.2	11.0	-	3.3*	$165/ton
ASHP Units 11.4 - 19.9 tons	-	10.7	10.6	-	3.2*	$150/ton
ASHP Units 20 - 63.3 tons	-	9.6	9.5	-	3.2*	$140/ton
GSHP Units (closed loop)	-	15.3	13.4**	-	3.6	$150/ton
GWSHP Units (open loop)	-	18.5	16.2***	-	3.1	$150/ton

* COP based upont 47°F DB and 43°F WB outdoor air temperature
** COP based upon GWSHP 77°F entering water.
*** COP based upon GWSHP 59°F entering water.

Table 4: ASHP units 5.4 tons or less incremental cost (Ref. 3)

Efficiency Level	Incremental Cost
SEER 14	$137/ton
SEER 15	$274/ton
SEER 16	$411/ton
SEER 17	$548/ton
SEER 18	$685/ton

METHODOLOGY AND ASSUMPTIONS

$EFLH_{Cool}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

$EFLH_{Heat}$ were determined from based prototypes building models on the California DEER study prototypes modified Illinois field data and scaled with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

Assumed ventilation rates complied with the requirements of ASHRAE standard 62.1 – 2004.

NOTES

Base line ground source heat pump SEER is based upon an entering temperature of 59°F entering water temperature.

REFERENCES

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, by GDS Associates, Inc. June 2007, pg. 6.
2. Comparison of Electric/Gas Fired Unitary equipment costs from DEER 2008 Database Technology and Measured Cost Data and Electric/Gas Fired Unitary and Heat Pump equipment costs from RSMeans Mechanical Cost Data.
3. DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
4. 0.9 is a typical value used for central HVAC equipment in many programs, the range is 0.74 to 1.0 with most being very close to 0.9, primary data has not been identified.
5. Minnesota 2015 Energy Code - TABLE C403.2.3(2) MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS.
6. ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment.
7. FES calculated EFLH from energy models based on California DEER study prototypes modified by Illinois field data with Minnesota weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3) 2012.
8. FES scaled EFLH from those provided in the Illinois Technical Reference Manual based on Minnesota weather data. EFLH for the Illinois Technical Reference Manual were based on California DEER study prototypes modified by Illinois field data to closely match EFLH from the modeling to those calculated from field data.

C/I Lighting - Lighting End Use

MEASURE OVERVIEW

Description: The commercial lighting measures use a standard set of variables for hours of use, HVAC cooling interaction effects, and coincident factors. The following section provides the algorithms used for energy savings and the tables of supporting information.

Algorithms: Unit kWh Savings per Year = (kW_{Base} - kW_{EE}) x Hrs x HVAC_Cooling_kWh_Savings_Factor

Unit Peak kW Savings = (kW_{Base} - kW_{EE}) x HVAC_Cooling_kW_Savings_Factor

Measure Lifetime (years) = see Table 3.

Unit Participant Incremental Cost = See Appendix B

Where:

kW_{Base} = Baseline fixture wattage (kW per fixture): see Appendix B

kW_{EE} = High efficiency fixture wattage (kW per fixture): see Appendix B

Hrs = Deemed annual operating hours from Table 2 based on building type

CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility system demand. CF will be determined based on customer provided building type in Table 2.

HVAC_Cooling_kWh_Savings_Factor = Cooling system energy savings factor resulting from efficient lighting from Table 1. Reduction in lighting energy results in a reduction in cooling energy, if the customer has air conditioning.

HVAC_Cooling_kW_Savings_Factor = Cooling system demand savings factor resulting from efficient lighting from Table 1. Reduction in lighting demand results in a reduction in cooling demand, if the customer has air conditioning.

HVAC_Heating_Penalty_Factor = Heating system penalty factor resulting from efficient lighting from Table 1.

Required from Customer/Contractor: Existing fixtures and quantities (retrofits only), installed fixtures and quantities, buildign type, HVAC system (heating only, heating & cooling, exterior/unconditioned).

DEEMED INPUT TABLES

Table 1: HVAC Interactive Factors by HVAC System (Ref. 2)

	HVAC Cooling kW Savings Factor		HVAC Cooling kWh Savings Factor		HVAC Heating Penalty Factor (Dth/kWh)
Lighting Measures	**Heating Only**	**Heating & Cooling**	**Heating Only**	**Heating & Cooling**	**Heating Only or Heating & Cooling**
All Except Exterior/Unconditioned	1.000	1.254	1.000	1.095	-0.0023
Exterior/Unconditioned Space	1.000	1.000	1.000	1.000	0.0000

Table 2: Deemed Peak Demand Coincidence Factors (Ref. 3) and Annual Operating Hours by Building Type (Ref. 4)

Building Type	CF	Hrs
Office	70%	4,439
Restaurant	80%	3,673
Retail	83%	4,719
Grocery/Supermarket	90%	5,802
Warehouse	70%	4,746
Elementary School	71%	2,422
Secondary School	58%	4,311
College	81%	3,540
Health	75%	5,095
Hospital	75%	6,038
Hotel/Motel	21%	3,044
Manufacturing	92%	5,200
Other/Miscellaneous	66%	4,576
24-Hour Facility	100%	8,766
Safety or Code Required	100%	8,766
Exterior lighting	0%	4,903

Table 3: Measure Life

Installed Techonology	Measure Life	Reference
Ceramic Metal Halide	13.0	8
Ceramic Metal Halide - Integrated Ballast	13.0	8
High Bay Fluorescent	15.0	6
LED Exterior Canopy	10.2	14
LED Exterior (Wall & Area)	10.2	14
LED Lamp	2.3	15
LED Luminaire	3.4	16
Low wattage plug in CFL	1.8	17
Low wattage T8	15.0	6
Pin-Based CFL	2.3	18
Pulse Start Metal Halide	15.0	9
CFL Standard to Low Wattage	8,000 hr	1
Controls	8.0	6
Exit Sign Retrofit with LED/LEC	16.0	6
Exterior Canopy/Soffit Retrofit with LEDs	50,000 hr	7
Exterior Wall Pack Retrofit with LEDs	50,000 hr	7
Parking Garage Fluorescent	15.0	6
High Pressure Sodium	15.0	19
LED Lamps	7.9	20
LED Luminaire	7.9	21
Pin-Based CFL	2.3	9
T5 Fixtures	15.0	6
T8 Fixtures	15.0	6
Refrigerator/Freezer Case LEDs	10.0	10
Stairwell Fixtures with Integral Occupancy	14.4	11
T8 Standard to Low Wattage Retrofit	36,000 hr	12
Energy Standard Exempt T12 HO ballasts for outdoor signs and electorn ci ballast T12s	15.0	6
Nonexempt 8 foot magnetic ballast T12s are 4 years in 2013, 3 years in 2014, 2 years in 2015, and 1 year in 2016	4, 3, & 2	13
T8 Optimization	15.0	6

METHODOLOGY AND ASSUMPTIONS

HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).

NOTES

New construction requirements and information is available in the New Construction section.

REFERENCES

1. Product life assumption of 8,000 hours determined through survey of on-line retailers, July 2012.
2. HVAC cooling and heating interactive factor data based on DOE2/Equest building simulation. The prototypes building models are based on the California DEER study prototypes (see http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf), and modified for local construction practices and code. Simulations were run using TMY3 weather data for the following cities in Minnesota: Duluth (Zone 1), St. Cloud (Zone 2), and Minneapolis-St. Paul (Zone3).
3. Database of Energy Efficient Resources 2008 Measure Energy Analysis Revisions Version 2008.2.05-09-11 Planning/Reporting Version
4. State of Illinois Energy Efficiency Technical Reference Manual Final Technical Version as of July 18th, 2012 Effective June 1st, 2012 Section 6.5. Illinois TRM summarizes recent studies including: DEER 2005, DEER 2008, ComEd FY1 and FY2 evaluations, AmerEn Missouri Final Report: Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, and Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
5. Lighting Efficiency input wattage guide, Xcel Energy, July, 2008, kW.
6. Database of Energy Efficient Resources 2008 Effective Useful Life Summary 10-1-08.
7. Product life assumption of 50,000 hours from Illinois Technical Reference Manual, July 2012, confirmed with survey of online retailers, July 2012.
8. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009.
9. Residential and Commercial/Industrial Lighting and HVAC Measures for use as Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM) June 2007 GDS Associates, Inc.
10. Assumes 6,205 hrs per year operation (17 hrs/day) and a lifetime of approximately 62,082 hours (this is the average rated life from DLC qualified product list). Accessed 7/31/12.
11. Xcel Energy 2013-2015 Triennial CIP Plan (Docket No. E,G002/CIP-12-447). Average of fixture lifetime (20 years) and control lifetime (~8 years).
12. Product life assumption of 36,000 hours determined from survey of on-line retailers, July 2012.
13. Measure life phase out is based on a combination of Texas Docket 39146 and the Illinois Statewide Technical Reference Manual. See methodology and assumptions for more details.
14. LED exterior canopy, area, and wall pack fixture rated hours of 50,000 is divided by the exterior operating hours of 4,903 to arrive at 10.2 years for measure

life.

15. LED lamp rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.
16. LED luminaire rated hours of 15,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 3.4 years for measure life.
17. Measure life for plug in low wattage CFL lamps is based on 8,000 hours of life divided by the average annual operating hours of 4,431 to arrive at 1.81 years.
18. CFL lamps rated hours of 10,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 2.3 years for measure life.
19. Xcel Energy uses 20 years in 2013-2015 Minnesota CIP Triennial Plan (Docket No. E,G002/CIP- 12-447), per communication with Commerce staff. Fixture may be considered permanent once installed. However, life was decreased to 15 years for consistency with maximum lifetimes for other technologies.
20. LED lamp rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for measure life.
21. LED luminaire rated hours of 35,000 is divided by the average operating hours (except safety, 24 hr, and exterior) of 4,431 hours to arrive at 7.9 years for
22. ANSI/ASHRAE/IES Standard 90.1-2010 edition.

C/I HVAC - Variable Speed Drives

MEASURE OVERVIEW

Description: This measure applies to variable speed drives installed on HVAC systems including:
- HVAC fans - supply fans, return fans, and cooling tower fans
- HVAC pumps - hot water heating and chilled water cooling pumps

The VSD will vary the speed of the motor in a HVAC application with a diversified load.

In the applicable HVAC applications, the power of the motor is approximately proportional to the cube of the speed, providing significant energy savings.

Actions: Modify, Replace Working (Retrofit), New Construction (limited sizes, see Notes)

Algorithms: Unit kWh Savings per Year = HP x Load_Factor x Conversion / Eff x Hrs x ESF
Unit Peak kW Savings = HP x Load_Factor x Conversion / Eff x ESF
Measure Lifetime (years) = 15 (Ref. 1)
Unit Participant Incremental Cost = See Table 4 (Ref. 2)

Where:
HP = Rated horsepower of new drive, assumed to be the same as associated motor.
Load_Factor = Motor load factor = 75% (Ref. 3).
Conversion = 0.746 (1 HP = 0.745 kW)
Eff = Efficiency of motor, if unknown see default values by size in Table 2 (Ref. 5)
Hrs = Annual operating hours, if unknown see default values by application in Table 1 (Ref. 4)
ESF = Energy Savings Factor per Table 3 (Ref. 6, 7).

Required from Customer/Contractor: Horsepower, application type (see Table 1), application (see Table 3), motor efficiency (optional), annual operating hours (optional).

DEEMED INPUT TABLES

Table 1: Deemed annual operating hours by application type (Ref. 4)

Application Type	Annual Operating Hours
Chilled Water Pump	2,170
Heating Hot Water Pump	4,959
Condenser Water Pump	2,170
HVAC Fan	5,236
Cooling Tower Fan	1,032

Table 2: Motor Efficiency (Ref. 5)

Horsepower (HP)	Motor Efficiency
5	0.87
7.5	0.88
10	0.90
15	0.90
20	0.91
25	0.91
30	0.92
40	0.92
50	0.93
60	0.93
75	0.93
100	0.93

Table 3: Energy Savings Factor (Ref. 6, 7)

Application Type	ESF
HVAC Pumps	
Hot Water Pump	0.482
Chilled Water or Condenser Water Pump	0.432
HVAC Fans, Supply or Return	
Constant Volume (no flow control)	0.535
Air Foil/inlet Guide Vanes	0.227
Forward Curved Fan, with discharge dampers	0.179
Forward Curved Inlet Guide Vanes	0.092
Fan Average (unknown type)	0.258
Cooling Tower Fan	0.249

Table 4: HVAC VSD Incremental Costs, Including equipment and installation costs (Ref. 2)

Horsepower (HP)	Fan	Pump
5	$1,840	$3,420
7.5	$2,620	$4,200
10	$2,640	$4,300
15	$2,740	$4,600
20	$3,520	$5,460
25	$4,540	$6,580
30	$4,840	$7,340
40	$4,960	$75,440
50	$6,780	$9,160
60	$10,260	$13,360
75	$12,380	$15,460
100	$15,340	$18,580

METHODOLOGY AND ASSUMPTIONS

Demand savings are assumed to be minimal, as it is assumed that demand savings for HVAC measures are defined as summer peak hour savings.

Savings are calculated based upon a constant speed baseline operation.

Variable speed does not include multi-speed (two or three speed) applications.

Costs do not include motor replacement cost.

Assumes existing motor is VFD compatible.

Savings and costs are based upon single motor application and do not consider series or parallel applications.

NOTES

Speed or capacity control is required by the 2015 Minnesota energy code by size and application; for VAV fan units greater than or equal to 7.5 Hp without variable pitch fan blades, non-multi-stage hydronic pumping systems with a design output greater than 300,000 Btu/h, heat rejection fans greater than or equal to 7.5 HP.

It is generally accepted that VSDs provide this capacity control for these sizes, and should be considered the baseline for New Construction.

Operation below 30% of design speed is not recommended.

REFERENCES

1. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.
2. CL&P and UI Program Savings Documentation for 2008 Program Year, total installation cost is double material cost, this includes labor and additional items such as sensors other required modifications.
3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for motor load factor data.
4. Pennsylvania Technical Reference Manual, June 2011, average of hours by application across all building types.
5. Average of Premium Efficiency Motor specification abd EPAct Motor specification averaged over all types and speeds, by horsepower.
6. CL&P and UI Program Savings Documentation for 2008 Program Year, savings factor based on bin spreadsheet calculation, all applications except cooling tower fans.
7. Cooling tower savings factor, Pennsylvania Technical Reference Manual, June 2011, savings based on building simulation.

C/I Motors

Version No. 2.0

MEASURE OVERVIEW

Description: This measure includes one-for-one replacement of working or failed/near-failure 1-200 hp motors with motors that meet or exceed NEMA Premium Efficiency levels in industrial and non-industrial applications, as well as installation of motors in new construction.

For replacement of working motors, the new motor efficiency must be at least NEMA Premium Efficiency. For replacement of failed/near-failure motors or new construction, the new motor efficiency must exceed NEMA Premium Efficiency.

Actions: Replace Working, Replace on Fail, New Construction

Algorithms: Unit kWh Savings per Year = HP x Load_Factor x Conversion x (1 / Eff_{Base} - 1 / Eff_{New}) x Hrs

Unit Peak kW Savings = HP x Load_Factor x Conversion x (1 / Eff_{Base} - 1 / Eff_{New}) x CF

Measure Lifetime (years) = 6 (Replace Working), 20 (Replace on Fail, New Construction) (Ref. 1, 2, 4)

Unit Participant Incremental Cost = Incr. Cost for EPACT to NEMA Premium Efficiency or EPACT to Enhanced NEMA Premium (Replacing Working); Incr. Cost for NEMA Premium Efficiency to Enhanced NEMA Premium (Replace on Fail and New Construction). See Appendix C (Ref. 6).

Where:

Hrs = Deemed annual operating hours by end use (non-industrial applications, see Table 2) or motor HP (industrial applications, see Table 1.)

Load_Factor = Motor load factor, deemed at 75% (Ref. 1, 4)

HP = Rated horsepower of new motor.

Eff_{New} = Efficiency of new motor.

= NEMA Premium Efficiency or NEMA Premium Efficiency + 1%. See Appendix C.

Eff_{Base} = Baseline motor efficiency.

= EPACT efficency (Replace Working), NEMA Premium Efficiency (Replace on Fail, New Construction). See Appendix C.

Conversion = Standard conversion from hp to kW = 0.746 kW/hp

CF = Coincidence Factor, assumed to be 0.78 (Ref. 1, 2)

Required from Customer/Contractor: New Motor Enclosure Type (ODP/TEFC), RPM, Horsepower, Efficiency; Action Type (Replace on Fail, Replace Working, or New Construction); Building Type and Application (see Table 2).

DEEMED INPUT TABLES

Table 1: Deemed annual operating hours by motor horsepower for industrial applications (Ref. 3)

Horsepower (HP)	Hours
5	2,745
7.5	3,391
10	3,391
15	3,391
20	3,391
25	4,067
30	4,067
40	4,067
50	4,067
60	5,329
75	5,329
100	5,329
125	5,200
150	5,200
200	5,200

Table 2: Deemed annual operating hours by building type and application (Ref. 4)

Building Type and Application	Hrs
Office HVAC Pump	2,000
Retail HVAC Pump	2,000
Hospitals HVAC Pump	2,754
Elem/Sec Schools HVAC Pump	2,190
Restaurant HVAC Pump	2,000
Warehouse HVAC Pump	2,241
Hotels/Motels HVAC Pump	4,231
Grocery HVAC Pump	2,080
Health HVAC Pump	2,559
College/Univ HVAC Pump	3,641
Office Ventilation Fan	6,192
Retail Ventilation Fan	3,261
Hospitals Ventilation Fan	8,374
Elem/Sec Schools Ventilation Fan	3,699
Restaurant Ventilation Fan	4,155
Warehouse Ventilation Fan	6,389
Hotels/Motels Ventilation Fan	3,719
Grocery Ventilation Fan	6,389
Health Ventilation Fan	2,000
College/Univ Ventilation Fan	3,631
Office Other Non-Industrial Application	4,500
Retail Other Non-Industrial Application	4,500
Hospitals Other Non-Industrial Application	4,500
Elem/Sec Schools Other Non-Industrial Application	4,500
Restaurant Other Non-Industrial Application	4,500
Warehouse Other Non-Industrial Application	4,500
Hotels/Motels Other Non-Industrial Application	4,500
Grocery Other Non-Industrial Application	4,500
Health Other Non-Industrial Application	4,500
College/Univ Other Non-Industrial Application	4,500
Industrial/Manufacturing	See Table 1

METHODOLOGY AND ASSUMPTIONS

Measure lives for replacement of failed motors or motors in new construction was 15-20 years in most TRMs prior to the EISA standard for motors taking effect in December 2010. No sources were found for lifetime of early replacement motors since most states have disallowed rebates for industrial Premium Efficiency motors. However, a review of several TRMs showed that for other measures, the lifetime of early replacements is typically about one-third of the full measure life. Therefore, the lifetime of this measure was set to 6 years (approximately one-third of 15-20 years.)

NOTES

According to the EISA standard, general purpose motors (subtype I) manufactured after December 19, 2010, with a power rating of at least 1 horsepower but not greater than 200 horsepower, shall have a nominal full-load efficiency that is not less than as defined in NEMA MG– 1 (2006) Table 12–12 (aka "NEMA Premium®" efficiency levels).

REFERENCES

1. NYSERDA (New York State Energy Research and Development Authority); NY Energy $mart Programs Deemed Savings Database - Source for coincidence factor, measure life, and motor load factor.
2. Franklin Energy Services review, November 2013.
3. United States Industrial Electric Motor Systems Market Opportunities Assessment, EERE, US DOE, Dec 2002 - Source for operating hours for industrial motors and source for motor load factor data (Tables 1-18 and 1-19).
4. Efficiency Vermont's Technical Reference User Manual, 2004 - Source for operating hours for commercial motors (p.15) and source for measure life and source for existing motor efficiencies and source for motor load factor default value.
5. CEE (Consortium for Energy Efficiency) Premium Efficiency Motors Initiative – source for premium motor efficiencies.
6. Xcel Energy Minnesota Electric and Natural Gas Conservation Improvement Program Plan for 2013-2015 (Docket No. E,G002/CIP-12-447) – source for incremental costs.